The Ghent urban heat island effect on freeze-thaw weathering of building stones

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1. Introduction

Climate plays a major role in the weathering of natural building stones. Many studies have focused on its impact in the past (e.g. Brimblecombe & Grossi 2009) as well as its potential impact in the future (e.g. Grossi *et al.*2007), often with special attention for our valuable heritage which has been exposed for the longest time (e.g. Brimblecombe, 2010). This work specifically investigates the influence of the urban heat island in Ghent on the weathering of Savonnières limestone by climatic analysis and both laboratory and computational simulations.

2. Climatic analysis

The climatic data of six places in and around the city of Ghent, situated in the northwest of Belgium, is provided by the MOCCA project (Caluwaerts and Termonia 2016) from 01/07/2016 until 30/06/2017. Parameterization of this climatic data leads to the evaluation of the difference in climate between urban and rural locations in Ghent. The main difference between both environments is the higher temperature, due to the urban heat island, and the lower wind speed in the city centre. The higher temperatures result in a decrease in the number of freeze-thaw cycles, the intensity of these cycles and the number of wet-frost days, thereby evidencing the decrease of freeze-thaw weathering potential in urban environments for moderate Cfb climates. The numbers are very comparable to what has been reported for a changing climate by Grossi *et al.* (2007). The lower wind speed leads to a lower wind-driven precipitation load and thus to less deep penetration of precipitation in the stone.

3. Laboratory simulations

Different freeze-thaw cycles were simulated in a climatic chamber for Melle (rural) and the Sint-Bavo School (urban), on an isolated wet and oven-dried Savonnières limestone sample. The temperature in the wet stone shows a zero curtain effect, which is due to the release of latent heat as a consequence of the phase transition of liquid water to ice. Only at Melle, this zero-curtain effect is breached and the stone cools further below zero, illustrating the intensity difference (Fig. 1a). Moreover, these simulations reveal that the impact of the urban heat island is biggest for freeze-thaw cycles under an open sky (UV-radiation as a proxy), where the higher intensity of a rural environment is tempered by the urban heat.

4. Delphin Simulations

Full year simulations of the Melle and Sint-Bavo School climates on Savonnières in the HAM-simulation program Delphin indicate differences in terms of temperature, moisture content, ice crystallization and freeze-thaw cycles. The outcome of these simulations is in accordance with the previous analysis, indicating shallower and less freeze-thaw cycles inside an urban stone (Fig. 1b). The higher moisture content in the Melle stone is a consequence of the higher amount of wind-driven precipitation at this location, which leads in combination with a lower temperature, to more and deeper ice crystallization, resulting in a higher probability of ice damage in this rural stone.

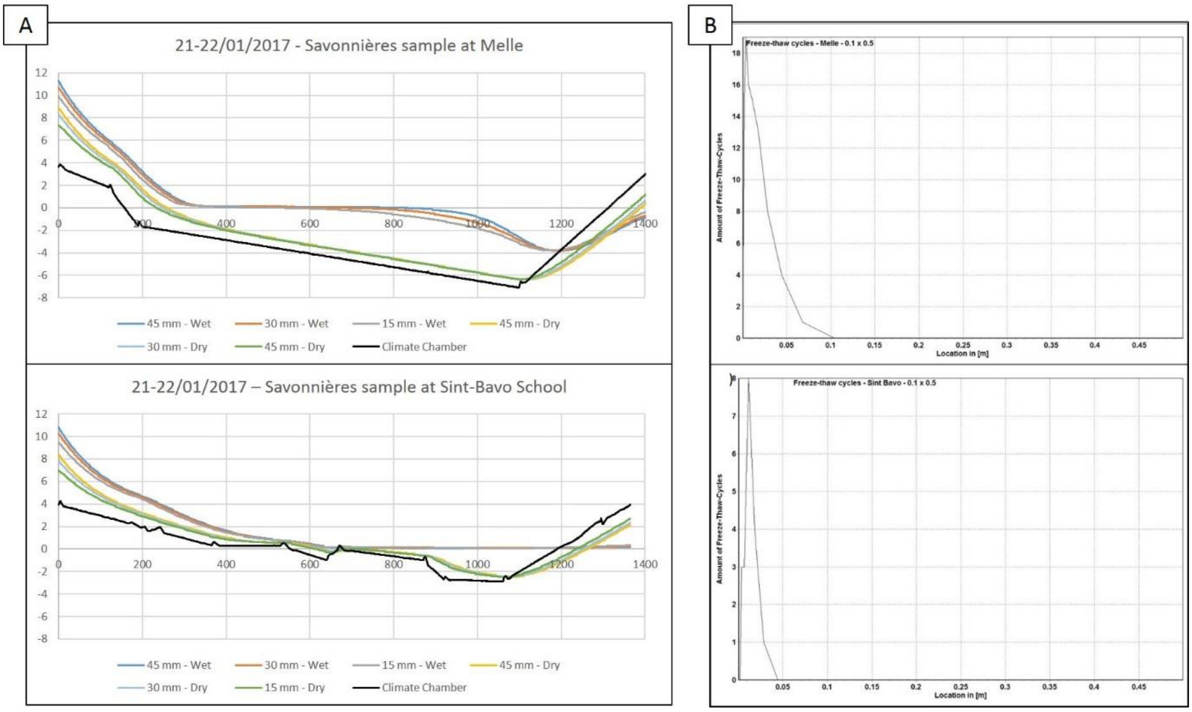

Figure 1: A) Temperature evolution of the climate chamber and inside both an isolated wet and dry Savonnières sample during the 21-22/01/2017 freeze-thaw cycle in Melle (rural, top) and at Sint-Bavo School (urban, bottom); B) Number of freeze-thaw cycles during the 2016-2017 winter in Savonnières limestone in Melle (top) and at Sint-Bavo School (bottom).

5. Conclusion

The climate analysis, experimental observations and computational simulations lead to the general conclusion that building stones in urban environments in a Cfb climate experience less freeze-thaw cycles and ice crystallization compared to stones in rural environments. The use of more years, or generation of reference years for both environments will allow further quantification of this effect. Moreover, since the obtained numbers are comparable to the projected impact of climate change reported in literature, it shows that the urban heat should be considered as very relevant in future work considering building stone weathering.

6. References

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